

Final Report for Partners Project S04-44687

Project Title: Application of High Resolution Mesoscale Models to Improve Weather Forecasting in Hawaii

University: University of Hawaii

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SECTION 1: Summary of Project Objectives

Since early 2002, we have conducted high resolution (1.5 km) experimental forecasts for the Island of Oahu (<http://www.soest.hawaii.edu/MET/Faculty/rsm>) using the NCEP (National Centers for Environmental Prediction) Mesoscale Regional Spectral Model (MSM) coupled with the Noah (NCEP, Oregon State University, Air Force and Hydrological Research Laboratory) land Surface Model (LSM) (http://www.emc.ncep.noaa.gov/mmb/gcp/noahls/README_2.2.htm). In this project, we would like to extend our efforts to other islands using the MM5/WRF model. To promote closer ties between research and operations, the weather modeling community is moving toward the Weather Research and Forecast (WRF) model as future modeling basis for both research and operations with horizontal grids down to 1-10 km resolution. We would like to test the performance of the Weather Research and Forecast (WRF) model for the Hawaiian Islands when it becomes available.

Section 2: Project Accomplishments/Findings

Accomplishments:

We have set up MM5 daily experiment numerical model runs for the State of Hawaii with a 9-km horizontal resolution, the nested 1.5-km Oahu, 1.5-km Kauai, 3-km Hawaii and 3-km Maui-Molokai domains. The daily model runs are initialized by the GFS (Global Forecast System) 0000 UTC (1400 HST) data and completed around 03:30 HST the next morning. The daily results are available to NWS forecasters (<http://www.soest.hawaii.edu/MET/Faculty/mm5/>).

Y. Zhang attended MM5/WRF workshop this summer with funding support from Dr. Chen's NSF grant. He has set up the test runs using WRF for the Hawaiian Islands. Results from our test

runs are posted at our website <http://www.soest.hawaii.edu/MET/Faculty/mm5/wrf.html>.

Findings:

Validations of the 10-km operational Regional Spectral Model (RSM) and the coupled Mesoscale Spectral Model (MSM) with an advanced Land Surface Model (LSM) forecasts during a one-month period from May 20 through June 20, 2002 are performed at three surface sites on the island of Oahu. Two heavy rainfall cases over the Hawaiian Islands are also simulated using the MSM/LSM. Over land with adequate representation of the terrain, the 1.5-km MSM provides better forecasts of surface variables than the 10-km operational RSM. However, there are still appreciable discrepancies between the MSM simulations and observations. Further improvements are achieved by coupling the MSM with the LSM. In particular, over-estimation of the surface wind speed and daytime cold biases experienced by the MSM are largely corrected in the coupled MSM/LSM.

Composite analyses of surface variables at three surface sites under different trade-wind conditions show that the observed diurnal cycles in 2-m temperature, 2-m dew point temperature and 10-m wind are better forecasted by the MSM/LSM than the MSM. The observed daytime minima in 2-m dew point temperatures during the strong trade-wind days at two urban sites are reproduced by the MSM/LSM. Our heavy rainfall case studies indicate that the high-resolution MSM/LSM has better capability in simulating localized rainfall distributions and airflows associated with the heavy rainfall events than the 10-km RSM/LSM. Major model bias is that the MSM/LSM produces excessive rainfall on the windward side of the island of Oahu with no rainfall downstream of the mountain ridges, in contrast to the observed rainfall distribution that shows the maximum rainfall axis occurring slightly downstream of the mountain ridges.

A high wind event (14-15 February 2001) over the Hawaiian Islands associated with a cold front is simulated using the National Centers for Environmental Prediction (NCEP) Mesoscale Spectral Model (MSM) coupled with an advanced Land Surface Model (LSM). During this period, a strong high-pressure cell moved to the northeast of the Hawaiian Islands following the passage of the cold front. The cell then merged with the semi-permanent subtropical high and resulted in windy conditions across the state of Hawaii. Comparisons between observations and model simulations at 10 surface sites show that the MSM/LSM reproduces the spatial pattern and magnitude of the surface wind better than the RSM/LSM.

The MSM/LSM predicts downslope windstorms and hydraulic jumps on the lee sides of the islands of Kauai and Oahu. The highest peaks of both islands are below the trade-wind inversion (~2100 m). In the case of high mountains with a peak height above the trade-wind inversion, weak winds are simulated on the lee side. At the exit region of the Alenuihaha Channel between the islands of Maui and Hawaii with high mountains, strong winds are forecasted with characteristics of gap winds and a hydraulic jump. The model also resolves the Waimea jet above the lee slopes of the Waimea Saddle between Mauna Kea and the Kohala Mountains of the island of Hawaii (or the Big Island). A hydraulic jump is forecasted in association with the Waimea jet and the strong winds over the southern corner of the Big Island. In contrast, the 10-km operational Regional Spectral Model (RSM) coupled with the LSM predicts uniform trade-wind flow for Kauai and Oahu. In addition, the

RSM/LSM forecasted strong winds are mainly located over the mountain ridges without extending to the lee slopes.

Sea breeze cases during 23 June to 28 June 1978 over northwest Hawaii are simulated using the National Centers for Environmental Prediction (NCEP) Mesoscale Spectral Model (MSM) coupled with an advanced Land Surface Model (LSM) with a 3-km horizontal resolution. Subjective analyses show that except for 27 June, the MSM/LSM-predicted onset time, duration, and vertical extent of the sea breezes agree well with observations. The largest forecasting errors for surface temperature occur at the coastal stations under strong trade wind conditions (e.g., 23 and 27 June). The model simulated rainfall distribution in association with sea breeze fronts is consistent with observations. Sensitivity tests demonstrate the modulation of sea breeze behavior by surface properties. High-resolution (1 km) MSM/LSM simulations for 23 and 27 June show improvements over the 3-km MSM/LSM in reproducing the observed sea breezes through a better representation of local terrain and a better simulation of orographically enhanced trades channeling through the Waimea Saddle. Deficiencies noted in the model simulations include (1) sea breeze speeds are more than $2\text{--}3\text{ m s}^{-1}$ lower than observations and (2) horizontal penetration of sea breezes is generally overestimated. These deficiencies in the model simulations are primarily related to two factors: one is the underestimation of the trade wind speeds in the initialization from the NCEP/NCAR reanalysis data that promote the farther penetration of the sea breezes, and the other is the uncertainties in the thermal properties of the lava rocks that affect the surface temperature and the sea breeze speed.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

One of the main benefits of MM5 data is having model guidance on a resolution comparable to the resolution used in the Hawaiian Islands Gridded Forecast Editor (GFE) domain. The existing operational high-resolution NCEP models, the RSM and the Eta, use a resolution no better than 10-km. Prior evaluations of model output at this resolution show that 10-km is still inadequate to accurately represent local circulations on all the islands. Since the operational GFE grid is at 2.5 km, it is vital for HFO to have model guidance at a comparable resolution in order to produce accurate forecast grids for the public. Over the next reporting period, we hope to incorporate MM5 data from this Partners Project into AWIPS for use as GFE guidance.

Section 4: Benefits and Lessons Learned: University Partner Perspective

The primary benefit to the university is the exposure of our students to operational forecasting and better understanding of forecast problems. Also, the project provides us the opportunity to conduct research related to problems that are important to operational forecasting. For example, one of our students, Y. Yang, used the MM5 output to study the weather conditions related to a small single-engine Piper Warrior tour airplane accident that occurred on April 18, 2004 over the southwestern Hawaii without any synoptic disturbances. The plane encountered extensive orographic clouds generated by local circulations and terrain. Y. Zhang received 3.5-month salary support as a graduate research assistant from this project in the spring semester 2004. He has completed his PhD dissertation research December 2004.

Section 5: Publications and Presentations:

PRESENTATIONS:

Zhang, Y., Y.-L. Chen, S.-Y. Hong, K. Kodama, and H.-M. H. Juang, 2004: Validation of the NCEP MSM coupled with an advanced LSM over the Hawaiian Islands. The Western Pacific Geophysics Meeting, Honolulu, Hawaii, 16-20 August 20, 2004.

Chen, Y.-L., Y. Zhang, S.-Y. Hong, K. Kodama, and H.-M. H. Juang: Validations of the NCEP MSM Coupled with the NOAA LSM over the Hawaiian Islands. The 5th Symposium on Fire and Forest Meteorology, Amer. Meteor. Soc., Orlando, Florida, 16-20 November, 2003.

Chen, Y.-L., 2004: High Resolution Weather Modeling over the Hawaiian Islands, guest lecture, *UH PET (Programming Environment and Training) Summer Institute: From Desktop to Supercomputer*, 26 July-6 August, 2004.

PUBLICATIONS:

Juang, H.-M. H., C.-T. Lee, Y. Zhang, M.-C. Wu, Y.-L. Chen, K. Kodama, and S.-C. Chen, 2004: Applying horizontal diffusion on pressure surface to mesoscale models on terrain-following coordinates. *Mon. Wea. Rev.*, (in press).

Zhang, Y., Y.-L. Chen, T. A. Schroeder, and K. Kodama, 2004: Numerical simulations of the sea breeze circulations over northwest Hawaii. *Wea. Forecasting*, (accepted with revisions).

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Section 6: Summary of University/Operational Partner Interactions and Roles

The NWS uses the MSM and MM5 websites to view the model outputs. The NWS has provided feedback to the University on both the model performance and the website contents.

Mr. Balbir Singh, a visiting intern of the NWS-HFO from the Fiji Meteorological Service this summer, is interested in high resolution MM5 experimental forecasts for Fiji Islands. Since early June, the University of Hawaii team has set up MM5 runs for Fiji islands with a 9-km regional domain covering $\sim 175^{\circ}\text{E}$ - 176°W , $\sim 13^{\circ}\text{S}$ - 20.5°S and 3-km nested domains for the islands of Viti Levu and Vanua Levu at the request of the Fiji Meteorological Service. Our daily runs are completed

at 5:30 am Fiji time. The daily runs are posted at our website and available to the forecasters of the Fiji Meteorological Service (<http://www.soest.hawaii.edu/MET/Faculty/mm5/FIJI.html>).

In addition, in collaboration with Drs. H.-M. Juang of NCEP and S-Y. Hong of Yongsei University, Korea and NWS-HFO, we summarized our results from high resolution simulations of summer trade-wind weather for Oahu, heavy-rainfall and high-wind events using MSM/LSM for possible publications.

Kevin Kodama from the Honolulu Forecast Office (HFO) is archiving weather data for use in model verification. Links to the UH MM5 web page were also added to the HFO internal web page for reference by the operational forecasters. Kevin is also working with Dr. Chen's group to port MM5 model output into AWIPS. The goal is to have MM5 data available for forecasters in N-AWIPS and D2D.